Suppression Of Wheat Stem Sawfly With Resistant Wheat

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Suppression Of Wheat Stem Sawfly With Resistant Wheat

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There is increasing interest in suppressing or managing insect populations in prescribed areas as a means of reducing crop losses. Well-organized measures applied to the total insect population in large areas may prove more effective and more economical than uncoordinated control efforts directed against small segments of a large population. The male sterility technique or similar genetic approaches for insect suppression have been considered in some detail by E. F. Knipling.[1] For many years chemicals have been used to suppress insects. The effect of resistant plant varieties on controlling insect populations on an area basis is still largely undetermined. However, it is known that highly resistant wheat varieties grown in large areas will markedly reduce populations of the Hessian fly (*Mayetiola destructor* (Say)).

It is the purpose of this report to consider the impact on the wheat stem sawfly (*Cephus cinctus* Norton) of growing resistant wheat. Also considered is how the coordinated rotation of resistant and susceptible wheats in community or regional programs might keep the wheat stem sawfly below economic damage levels and still permit the growing of susceptible varieties, which might have certain agronomic characteristics superior to those of the best resistant varieties.

Theoretical Trend of Insect Populations

Knipling[2] projected the theoretical trend of a hypothetical uncontrolled insect population increasing fivefold per generation, as shown in the following model:

Generation	*Insects per unit area (millions)*
1	1
2	5
3	25
4	125

[1] KNIPLING, E. F. THE POTENTIAL ROLE OF THE STERILITY METHOD FOR INSECT POPULATION CONTROL WITH SPECIAL REFERENCE TO COMBINING THIS METHOD WITH CONVENTIONAL METHODS. U.S. Agr. Res. Serv. ARS 33–98, 54 pp. 1964.

[2] See footnote 1.

He also projected the trend of such a population when subjected to control with insecticides and other measures.

The wheat stem sawfly has only one generation a year. However, its increase in a favorable environment could be expected to follow in several years the same general trend that multiple-generation insect species might follow in 1 year. Starting with a theoretical population of 1 million parents the first year in a given area, we could on the basis of a fivefold increase expect the sawfly population in susceptible wheat to increase to 5, 25, and 125 million in the second, third, and fourth years, respectively. Such increases could be expected until the maximum density for the environment has been reached. The actual growth rate of wheat stem sawfly populations has not been investigated. However, in principle the preceding model could be realistic.

We might establish a population model based on 90-percent suppression, which was suggested by Knipling as representing the effect that might be expected from using insecticides against many destructive insects.

If 90-percent suppression each year due to resistant wheat is realistic for sawfly populations, a population trend in areas planted to Rescue wheat should follow the trend shown in the next model, provided a fivefold increase is realistic for an uncontrolled population.

Generation	*Insects per unit area*
1	1,000,000
2	500,000
3	250,000
4	125,000
5	62,500

Based on this model, the population would gradually decline, but many years would be required to reduce it to zero.

Field Observations on Sawfly Population Trends

In 1950, tests were conducted on the wheat stem sawfly on the Glen Inbody ranch, 12 miles northwest of Choteau, Mont. Wheat in the area was infested nearly 100 percent. This same year, Rescue, which had only recently been released by the Canadian Department of Agriculture, was extensively grown for the first time in this area. Each successive year thereafter as the acreage of Rescue was increased, sawflies decreased until in 1955 host plant-resistant tests could no longer be conducted because of low populations. In 1956, or the seventh year after resistant wheat was grown, the sawfly populations were so reduced that infestations were difficult to detect.

Tests were next conducted on the Fred Swenson ranch, southwest of Choteau. The same thing happened in this area. The farmers planted resistant varieties and the sawfly virtually dis-

appeared within 6 or 7 years. These observations indicate that the rate of decline of sawflies probably exceeds that projected for the hypothetical population in model 2, which is based on 90-percent suppression of the reproductive potential each generation.

Holmes and Peterson,[3] Canadian scientists, conducted field tests that demonstrate the suppression effect of Rescue on sawfly populations. They showed that sawflies developing on Rescue for 5 years gradually declined to zero. The observations further support the conclusion that population suppression substantially exceeds 90 percent in relation to uncontrolled populations.

Based on these field studies in Montana and Canada, it seems safe to conclude that in appraising the degree of population suppression due to growing resistant wheat varieties such as Rescue, it would be valid to consider a suppression factor substantially greater than 90 percent each year or each generation.

Precise information is not available on the degree of buildup of wheat stem sawfly populations in new susceptible wheat varieties. However, it is the general opinion of research scientists working on this problem that under favorable conditions migrant populations from infested fields, volunteer wheat, or grasses would build up in new susceptible wheat crops to economic damage levels in about 4 or 5 years.

Theoretical Trend of Sawfly Populations in Susceptible and Resistant Wheats

We will establish a hypothetical model based on a fivefold increase from a low density on susceptible wheat and estimate the growth of a sawfly population and in turn the wheat infestation or cutting trend. We will assume a starting immigrant population as low as 10 males and 10 females per acre of susceptible wheat.

Research has indicated that one female can infest on an average about 38 stems. However, some mortality will occur after infestation. Accordingly we will assume that for each female 20 mature larvae will develop and cut the stems of susceptible wheat during the growing season. Of this number, half the larvae will produce adults for the next generation the following spring. This rate of increase will be assumed so long as the population has not approached 100-percent infestation. As the infestation approaches 100 percent, the number of larvae produced and the number of adults surviving will decline because of increased parasitism, predation, and other factors that retard the growth of high-density populations. Based on these parameters, the sawfly population and cutting trend would be as shown in table 1.

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[3] HOLMES, N. D., and PETERSON, L. K. EFFECT OF CONTINUOUS REARING OF RESCUE WHEAT ON SURVIVAL OF THE WHEAT STEM SAWFLY, CEPHUS CINCTUS NORT. (HYMENOPTERA: CEPHIDAE). Canad. Ent. 89: 363–365. 1957.

Based on this hypothetical model, an economic population could be expected to develop on susceptible wheat in 5 or 6 years. This closely agrees with field observations. Thus the assumed fivefold increase potential per generation until the population reaches near maximum density is probably sufficiently representative of an actual increase to serve as a basis for developing models to appraise the effect of resistant varieties on population trends. The size of a starting insect population would, of course, markedly affect the number of years that infestations must develop before reaching economic levels. However, a low population of 10 males and 10 females per acre would seem to be realistic for a population existing at a minimum detectable level.

We will now establish a hypothetical model that we believe could depict the trend of a sawfly population after it has reached a high density on susceptible wheat and then subject it to the planting of resistant wheat. Some new parameters must be established for projecting such a model.

For the resistant solid-stemmed wheat varieties, we know that only about 10 percent of the stems will be cut under circumstances where susceptible wheat may show nearly 100-percent cutting. Therefore, we will assume 90-percent reduction in larval populations before stem cutting. It also seems logical to assume that the larvae that become established in solid-stemmed wheat may be less likely to complete development as adults. Therefore, we will assume that only one-fourth of the larvae remaining after cutting will produce adults for the next generation. In susceptible wheat we have assumed that half the larvae will survive as adults.

Based on these assumed suppression effects, we will establish a population model developing on resistant wheat. We will start with the maximum population density. It is assumed that the natural population has reached its maximum level and cannot increase further because of limitations imposed by the number of wheat stems available for infestation and other population suppression factors associated with high-density populations. If the basic parameter is valid that each female under low to moderate density levels will produce sufficient larvae to cut 20 stems of a susceptible variety and if each acre has 1 million wheat stems, it

TABLE 1.—*Calculated trends of wheat stem sawfly population on susceptible wheat based on fivefold increase each year and of cut stems per acre*

Year	Female sawflies	Cut stems
	Number	*Number*
1	10	200
2	50	1,000
3	250	5,000
4	1,250	25,000
5	6,250	125,000
6	31,250	625,000

TABLE 2.—*Postulated decline of wheat stem sawfly population on susceptible wheat and of cut stems per acre after planting resistant solid-stem wheat in high-density sawfly area*

Year	Natural sawfly population [1]	Cut stems
	Number	*Percent*
1	100,000	10
2	[2] 25,000	2.5
3	6,250	.625
4	1,560	.156
5	390	.039
6	98	.001

[1] 50 percent each of males and females.
[2] Model assumes 25 percent of overwintering larval population remaining after cutting will produce adults for next generation. Each female in resistant wheat would develop an estimated 2 larvae, which will cut 2 stems.

can be postulated that 50,000 females per acre could produce sufficient larvae to cut 100 percent of these stems. Based on random deposition of eggs in stems, probably many more than 50,000 females would be required to actually infest and cut 100 percent of these stems, but the assumption of a maximum of 50,000 adult females per acre seems sufficiently valid to proceed with the theoretical projections. Based on the various parameters stated, the sawfly population developing on susceptible wheat and the stem cutting would decline as shown in table 2.

Based on this hypothetical model, we would expect a wheat stem sawfly population existing at a maximum density to virtually vanish by the sixth year after planting resistant wheat in a large area. Infestation levels as low as 0.001 percent, which would theoretically occur by the sixth year, would be difficult to detect. The theoretical cutting trend on resistant wheat, based on the various parameters stated, does not disagree markedly with the findings in the previously described field observations.

If the rate of decline on resistant wheat is reasonably realistic and if the projected fivefold increase of low to moderate sawfly populations developing on susceptible wheat is also reasonably valid, it should be possible to project trends of sawfly populations and stem cutting when resistant and susceptible wheat varieties are grown alternately throughout a community or a region. The objective would be to maintain sawfly populations below economic damage levels on both susceptible and resistant wheats during each rotation.

Crop Management and Sawfly Control

Based on the calculated population trends of the sawfly developing on susceptible and resistant wheats, we propose to project a community or regional program that would permit the rotation of

susceptible and resistant wheats without experiencing significant economic losses due to sawfly damage.

We will assume that in certain areas it would be desirable and profitable to grow currently available susceptible varieties in lieu of currently available resistant ones if wheat stem sawflies can be held below economic damage levels. Growing susceptible varieties might be justified on the basis of increased yield, better milling and baking qualities, higher resistance to disease and drought, esthetic characteristics, or simply farmer preference.

We will initiate a theoretical rotation scheme on the assumption that the overall wheat stem sawfly population has already become virtually extinct by clean cultivation and growing resistant wheat or other crops immune to sawfly attack such as oats and barley. Starting populations with which we are concerned are the migrants from other wheat grown in the area and from native grasses. The total starting population is estimated to be 10 males and 10 females per acre per year.

Before projecting such a program we should consider what constitutes an economic level of sawfly damage. Munro [4] estimated that wheat losses due to fallen heads and kernel shrinkage are about 2 bushels per acre when infested at 33 percent. This infestation would represent about 20-percent cut stems. At $1.50 per bushel, this would be a loss of $3 per acre. Losses, of course, are considerably greater in fields where lodging is heavy and cut stems cannot be collected from the ground with a pickup reel. Based on these estimates, a 10-percent sawfly cutting level might be assumed to reduce yields by about 1 bushel per acre or a loss of about $1.50 per acre. We will assume that the growers want to keep sawfly cutting below 10 percent in order to benefit by growing susceptible varieties.

We will project the trends of the sawfly populations and of cut stems based on a rotation program with 3 years of susceptible followed by 2 years of resistant wheats.

The sawfly cutting levels each year were calculated for a 10-year period or two cycles of 5 years each. The dynamics of sawfly populations developing on susceptible and resistant wheats as postulated for tables 1 and 2, respectively, were followed in calculating the population and infestation trends during the 10-year period. All basic parameters are the same as those previously discussed. The results are shown in table 3.

Based on the parameters established, the results in table 3 indicate that a rotation program with 3 years of susceptible and 2 years of resistant wheats in a wheat-growing community would prevent a sawfly cutting level as high as 10 percent, which is assumed to be the maximum infestation that could be tolerated in susceptible wheat without loss to the grower who prefers susceptible varieties. The theoretical maximum sawfly cutting

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[4] MUNRO, J. A. WHEAT STEM SAWFLY AND HARVEST LOSS. N. Dak. Agr. Expt. Sta. Bimo. Bul. VII (No. 4): 12–16. 1945.

TABLE 3.—*Calculated trends of wheat stem sawfly population and of cut stems per acre in 10-year rotation program with susceptible and resistant wheats*

Type of wheat and year	Female sawflies	Cut stems
	Number	*Percent*
Susceptible		
1	[1] 10	0.02
2	60	.12
3	310	.62
Resistant		
4	1,560	.31
5	400	.08
Susceptible		
6	110	.22
7	560	1.12
8	2,810	5.62
Resistant		
9	14,060	2.81
10	3,525	.70

[1] A minimum population of 10 males and 10 females per acre is assumed to occur each year because of wild hosts and volunteer wheat growing in the area, in addition to sawflies developing on cultivated wheat.

would be 5.6 percent during the eighth year. This maximum cutting level should keep losses well below $1.50 per acre per year. In 6 of the 10 years, susceptible wheat could be grown. In the absence of losses due to the sawfly, which should average substantially less than 1 bushel per acre, profits to the wheat farmers would accrue to the extent that growing susceptible varieties in the area would increase income over that expected from growing resistant varieties.

Such a program should cost relatively little, but it would require good organization and full participation by all growers.

In studying the population and cutting levels for the 10-year period, it is noted that the population trend is upward during the second 5-year period. Theoretically if susceptible varieties were again grown for 3 successive years starting in the 11th year, sawfly cutting would substantially exceed the assumed 10-percent economic level by the 13th year. Changing the program to growing susceptible wheat for 2 years followed by resistant wheat for 3 years should bring the level down to where the program could again be continued on a 10-year cycle of producing susceptible wheat for 3 years and resistant wheat for 2 years.

Discussion

Theoretical calculations based on various parameters that seem reasonably valid suggest that when the starting sawfly population

is low the insect can be held below the economic damage level by growing susceptible wheat for 3 years and resistant wheat for 2 years in rotation. Available information on the economic advantages, if any, of growing susceptible over resistant varieties in sawfly areas should be studied to determine whether a program such as that proposed would be justified.

If such a study indicates an economic advantage in developing such a program, field tests should be conducted to determine the validity of the conclusions reached on the basis of theoretical calculations. Such tests could be carried out with a minimum of expense and effort by using such a rotation program (3 years susceptible, 2 years resistant) for at least 5 years. These tests could probably be conducted in areas where resistant Rescue wheat has been grown continuously for many years and sawfly populations are low. Reasonable isolation of the test area from high-density sawfly areas would be needed. However, since the insect flies close to the ground and seldom, if ever, travels more than 1 mile in search of an oviposition site, it should not be difficult to minimize sawfly migrations into the test fields from outside the area.

Some infestation pressure should occur, however, to determine whether the rotation method will accomplish the objective. The degree of reinfestation could probably be regulated fairly closely to the desired level by plowing under and destroying infested stubble, grasses, and volunteer wheat in the bordering cultivated areas to reduce sawfly migrant populations or perhaps by rearing and releasing sawflies to increase migrant populations.

There is some evidence that native grasses under modern farming and grazing practices are of minor importance in maintaining wheat stem sawfly infestations in wheat-growing areas. In some areas, populations may virtually be eliminated by growing resistant wheat alone. The primary purpose of the appraisal in this report is to estimate quantitatively, based on limited information, the degree of sawfly suppression that might be achieved by growing resistant wheat throughout an area. If the actual numbers of sawflies per unit can be reduced to low levels calculated by growing resistant wheat, the alternate growing of resistant and susceptible wheats in a well-coordinated program should be possible. The possibility of employing sterile insects to maintain noneconomic populations after drastic suppression of the insect by growing resistant wheat should also be considered.

Some practical experiments in suitably isolated areas would offer an excellent opportunity to gain more quantitative information than is now available on the dynamics of sawfly populations developing on susceptible and resistant wheats. Based on field observations and on available biological information regarding this insect, the population models in this hypothetical study are not likely to deviate widely from trends of actual sawfly populations developing on susceptible and resistant wheats. However, carefully controlled experiments under natural conditions would be necessary to determine the magnitude of any deviations from the theoretical projections.

If information can be obtained on the degree of suppression based on the insects remaining per unit area when resistant wheat is grown for several years in succession, and if the rate of increase on susceptible wheat can also be determined quantitatively, we would have a better basis on which to further develop and project practical area suppression programs. Such programs might include a rotation scheme such as that proposed or releasing sterile insects to maintain suppression.

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